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# DEVELOPMENT OBJECTIVES
# PRECISE MEASUREMENT STUDY

## 1. INTRODUCTION

These objectives describe the background, concept and requirements of a Government-sponsored research and development program in precise measurement (or precision mensuration) as it relates to the imagery exploitation process.

## 2. BACKGROUND

Methods and instruments to obtain measurements of imagery on reconnaissance type aerial photography have developed in a somewhat piecemeal manner since World War II. Present practices range from simple comparison measurements using tube magnifiers to complex measurements on comparators on-line to computers. The degree of accuracy claimed in obtaining imagery measurements by these methods is questionable and has come under continuous fire.

A lack of knowledge concerning specific requirements, accuracies, and capabilities in the acquisition - exploitation - utilization, interrelationship is handicapping the mensuration effort.

The ability of the photogrammetrist and interpreter to measure is limited by: accumulative errors, the representative math models, their physical environment, and functional parameters such as the imagery he can see, the controls he can manipulate, and the item to be measured. These conditions, when combined with the design features of a measuring instrument result in the ultimate precision of the mensuration process.

## 3. CONCEPT

This program is directed toward: the investigation and establishment of the accuracy requirements of the Users by category; the analysis and determination of the qualitative and quantitative parameters of the various acquisition systems; and the evaluation and proposal of procedures and instrumentation necessary to achieve the precision required in the exploitation processes.

It should be emphasized that this study is not directed toward developing acquisition systems, but toward the use of information and data on cameras and films and their interrelationship and error contributions in order to produce precise measurements to fulfill the User's requirements.

## 4. GENERAL DESCRIPTION

The objective of this program is to study the User's requirements, the acquisition system's capabilities, and the precision mensuration capability of the exploitation system as a single, integrated package. The desired accuracy, the quantity, the time required, and the various categories of measurements required by the User will be evaluated in relation to the resolution, the contrast, the film stability, and the geometry of present and proposed acquisition systems and their associated errors. Further, present measuring instruments will be evaluated, recommendations made, and specifications generated to provide for future requirements.

The goal of this program is to obtain reliable information and recommendations as to improving and developing measurement systems commensurate with proposed acquisition systems and User's requirements.

This goal will be accomplished through: an extensive literature search, a thorough investigation of requirements, a scientific evaluation of experimental and operational data, and the creation of analytical and experimental models.

## 5. DETAILED OBJECTIVES

### 5.1. Review of User's Requirements

5.1.1. Prepare a list of: Users (by type), the frequency of the requests, the number and type of measurements requested, and the response time required.

5.1.2. Visit the User's facilities, establish their requirements by desired accuracy, the use of the measurements (e.g., R&D, model makers, analyst, etc.) and determine their projected needs.

### 5.2. Study of Acquisition Systems as Related to Mensuration

5.2.1. Review present Operation Systems to Determine:

5.2.1.1. Accuracy of Ephemeris Information.

5.2.1.2. Geometric strength and types of format (e.g., frame, pan, strip).

5.2.1.3. Quality of optics.

5.2.1.4. Film and Emulsion. Stability, MTF, Resolution.

5.2.1.5. Atmospheric Effects - reduction in contrast and geometric deformations.

5.2.1.6. Thermal and inertial effects.

5.2.1.7. Dynamics of Panoramic and Strip photographic system.

5.2.1.8. Internal Orientation of Camera, focal length, lens distortions, and principal point location.

5.2.2. Review Proposed Systems to Determine:

5.2.2.1. Theoretical and computed accuracy and reliability of positioning.

5.2.2.2. Programmed and proposed cameras.

5.2.2.3. Proposed film and emulsion types. Thin Base, UTB, Color.

5.3. Obtain and review inputs from other Government sponsored research and study.

5.3.1. Typical research programs that are currently in progress and from which information will be available are as follows:

5.3.1.1. Image Analysis

5.3.1.2. Human Factors

5.3.1.3. Precision Stereo Comparator

5.3.1.4. Automatic Stereo Scanning

5.3.2. The selected contractor will in turn be expected to supply data and information to the contractors on the above listed programs.

5.4. Perform a detailed evaluation and analysis based upon the present and proposed acquisition systems and the User's requirements to establish the necessary accuracy required by the various components that use the measurements in relation to the quality of imagery obtained by the camera/film combination.

5.5. Evaluate Operation Procedures

5.5.1. Evaluate the various mensuration procedures that are in use.

5.5.2. Evaluate the accuracy of input parameters such as:

5.5.2.1. Accuracy of positioning system and time velocity readout.

5.5.2.2. Accuracy of data reduction. Stellar readout procedures.

5.5.3. Evaluate the math models representing perspective transformations and the mono and stereo computer programs that are in operational use.

5.5.4. Reproduction type film (Dupe Pos.) Stability, Resolution, MTF, Proposed improved film?

5.6. Evaluate Film Base Stability as Related to:

5.6.1. Processing of original and changes caused by it.

5.6.2. Reproduction methods and comparison of duplicate positives with original.

5.6.3. Chip vs. roll storage for dimensional changes.

5.7. Review Present Mensuration Equipment to Determine Objectively:

5.7.1. The accuracy and time to accomplish various mensuration tasks.

5.7.1.1. Vectorial mensurements.

5.7.1.2. One stage, two axis measurements (Monocular).

5.7.1.3. Stereo viewing but measuring with one stage, two axis system.

5.7.1.4. Stereo, two stage, four axis meausrements.

5.7.1.5. Measurement of height of objects.

5.7.2. The effect of viewing systems upon the mensuration process.

5.7.2.1. Anamorphic effects.

5.7.2.2. Magnification, resolution and other factors affecting mensuration.

5.7.2.3. Field of view

5.7.2.4. Contrast

5.7.2.5. Effect of curvature of field.

5.7.3. Study film holddown systems and determine their effects upon measurements.

5.7.4. Viewing Illumination

5.7.4.1. General vs. high intensity spot.

5.7.4.2. Effects of the amount of light at the eye, the color temperature, etc. on the accuracy of measuring and pointing.

6. TECHNICAL REQUIREMENTS

6.1. Provide consultation to the Government in the precise measurement field.

6.2. Have an expert awareness of past and present research in this field so as to prevent duplication.

6.3. Have the capabilities to undertake studies to determine the most desirable mensuration procedure for a task.

6.4. Be capable of undertaking practical experimentation as well as the theoretical approach on imagery measuring problems.

6.5. Be capable of determining the dynamic range capabilities and limitations of possible systems utilizing film inputs.

6.6. Conduct studies to determine the subsystems that require a major research effort.

6.7. Determine weak links in the mensuration process.

6.8. Generate Specifications that should be incorporated into immediate and future mensuration equipment.

6.9. Prepare Cost vs. Performance Curves for the mensuration tasks, instruments, the degree of precision, and the camera/film taking system.

7. AREAS OF INVESTIGATION

It is expected that the contractor will be able to obtain some of the information from technical publications and classified reports as well as from other prime contractors. It is anticipated that the majority of the information will have to be obtained through the contractor's investigation.

The program will cover all the areas mentioned in this section (7). The contractor may suggest any other areas that he deems important.

7.1. Acquisition System Errors

7.1.1. Taking camera.

7.1.1.1. Type of camera configuration - frame, pan, strip.

7.1.1.2. Calibration of cameras - residual coordinate errors in past systems.

7.1.1.3. The flatness or planeness of the film in the camera during the taking period.

7.1.1.4. The temperature and humidity within the camera.

7.1.1.5. Pan and Strip System Errors. Scan Velocity and Film Velocity variations. IMC Errors.

7.1.2. Original film in taking camera

7.1.2.1. Type of film and base thickness - thin, UTB, color.

7.1.2.2. Amount of tension on transport system.

7.1.2.3. Thickness variation in the film.

7.1.2.4. Effects and reaction of emulsion.

7.1.3. Camera lens/film relationship.

7.1.4. Aircraft/camera attitude determination methods. (Pitch, roll and yaw).

7.1.5. Atmospheric refraction effect.

7.1.6. Ephemeris Errors

7.1.6.1. Altitude

7.1.6.2. Latitude and Longitude

7.1.7. Time Errors (absolute or differences).

7.2. Processing Errors

7.2.1. Original Film - Stability of thin film, UTB and the errors introduced by manipulation of the control parameters.

7.2.2. Duplicate material - Reproduction and processing changes and errors.

7.3. Measuring Errors

7.3.1. Comparator

7.3.1.1. Type - Stereo, Mono

7.3.1.2. Measuring engine accuracy

7.3.1.3. Viewing magnification

7.3.1.4. Illumination System

7.3.1.5. Method of film holddown and its affect.

7.3.1.6. Effects of correlation and anamorphs.

7.3.1.7. Accuracy of pointing with various reticles.

7.3.1.8. Apparent size of reticle (dot) in the image plane in relation to the least count to measurement.

7.3.1.9. Encoders and their reliability.

7.3.1.10. Stage Drives and ways accuracy.

7.3.1.11. Film Platen Stability - Expansion, sag, etc.

7.3.2. Film on the Comparator

7.3.2.1. Heat effects of light sources.

7.3.2.2. Effect on moisture content of film by vacuum holddown.

7.3.2.3. Emulsion creep or warping.

7.3.2.4. Comparison of measurements, emulsion up and down.

7.3.2.5. Comparison of measurements on thin, UTB and Standard Base.

7.3.2.6. Effects of air puck holddown.

7.3.3. Accuracy of the math model representing perspective transformations and computer programs.

7.3.4. Error Analysis and Classification

7.3.4.1. Type of errors - systematic, random.

7.3.4.2. Frequency - periodic, random, continous.

7.3.4.3. Location - Instrument, observer, techniquest.

7.3.4.4. Cause - recurring erratic.

7.3.4.5. Detection - comparison, reappraisal.

7.3.4.6. Remedy - Replace or correct.

7.3.4.7. Prevention - Education, training, controls.

7.4. Analysis and Experimentation

7.4.1. Prepare graphs, nomograms, etc. to indicate the various errors for camera - film-process - comparator relationships.

7.4.2. Prepare cost performance curves as per mensuration instruments and encoders vs. accuracy.

7.4.3. Establish calibration methods and techniques for the mensuration instruments presently in use.

7.5. The present and planned trend, in photographic bases for aerial reconnaissance systems, appears to be toward thinner based films. The Thin and UTB films are not as dimensionally stable as their predecessors and will, therefore, cause some problems in mensuration. The demand for accuracy of dimensions for technical reporting has increased in the past and is expected to grow ever demanding in the future.

The lack of stability in the Thin and UTB increase the need for high precision measurements instead of relaxing the requirement as might be expected. Very precise measurements will be required over both long distances (20 inches) as well as small distances (less than 1mm) to enable the operator to determine the changes the film and the imagery has undergone in acquisition, processing and exploitation.